THE FAUNA OF THE PORTRANE LIMESTONE

1. THE INARTICULATE BRACHIOPODS

BY

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By A. D. WRIGHT

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SYNOPSIS

This paper is the first of a series by several authors describing a large fauna which has been etched out of the Portrane Limestone. The limestone is of Upper Ordovician age, although the precise horizon has not yet been satisfactorily established. One of the objects of the study is to use the large fauna now available to settle this question. In this part, an introduction to the work is given, followed by a systematic description of the inarticulate brachiopods, covering a total of fifteen genera, including one new genus, *Rowellella*, and eight new species.

I. INTRODUCTION TO THE PORTRANE LIMESTONE

SITUATED on the coast of Co. Dublin, Eire, about twelve miles north of the capital, is the small but interesting inlier of Portrane, where Lower Palaeozoic rocks are exposed on the eastern edge of a tract of what is dominantly Lower Carboniferous country. Within the rock sequence of the inlier occurs a limestone series, the Portrane Limestone. The present paper is the first of a series of papers describing the fauna of this limestone, or more specifically, of an horizon within the limestone sequence. This horizon has yielded an extraordinary diversity of invertebrate stocks, particularly of brachiopods and arthropods. The exceptionally large fauna will, it is hoped, settle finally the problem of the exact age of the Portrane Limestone within the Upper Ordovician. It is also expected that this fauna will contribute towards the correlation of the Upper Ordovician rocks not only within the British Isles, but also with those of Eastern North America and Scandinavia whose faunas are already known to have affinities with those of Britain.

Due to the large size of the brachiopod fauna it has been necessary to divide it into the two classes. This first part of the study is concerned with the inarticulate brachiopods ; the description of the articulate forms will follow in due course. The arthropods, which also form a major part of the fauna, will be described by Dr. W. T. Dean of the British Museum (Class Trilobita) and Dr. Gunnar Henningsmoen of the Paleontologisk Museum, Oslo (Class Ostracoda) ; I am very pleased to have their co-operation in this project. These two groups will form separate parts of the series.

In the final part, a complete faunal list will include the various other phyla as well as the brachiopods and arthropods, which are present either in a poor state of preservation or else in quantities which are too small to justify the publication of a separate *Bulletin*. In this part also will be included a summary of the conclusions as to the dating of this horizon, which will combine all the faunal evidence available.

II. HISTORICAL SUMMARY

A description of the geology of the inlier was first given by Medlicott (1853), in which he listed the sixteen fossil species previously recorded by M'Coy (1846) as coming from Portrane. Du Noyer, of the Irish Geological Survey, gave a description of the area (Du Noyer, 1861 : 11, 12) which also included a list of some fifty species identified by Baily. This list was revised later (Baily, 1880 : 82) and in the revised form was included by Sollas (1895 : 101) in his account of the geology of Dublin and its neighbourhood.

The area was remapped by Gardiner & Reynolds (1897) who gave the first precise data on the fossil horizons and localities. The faunas of their principal fossiliferous

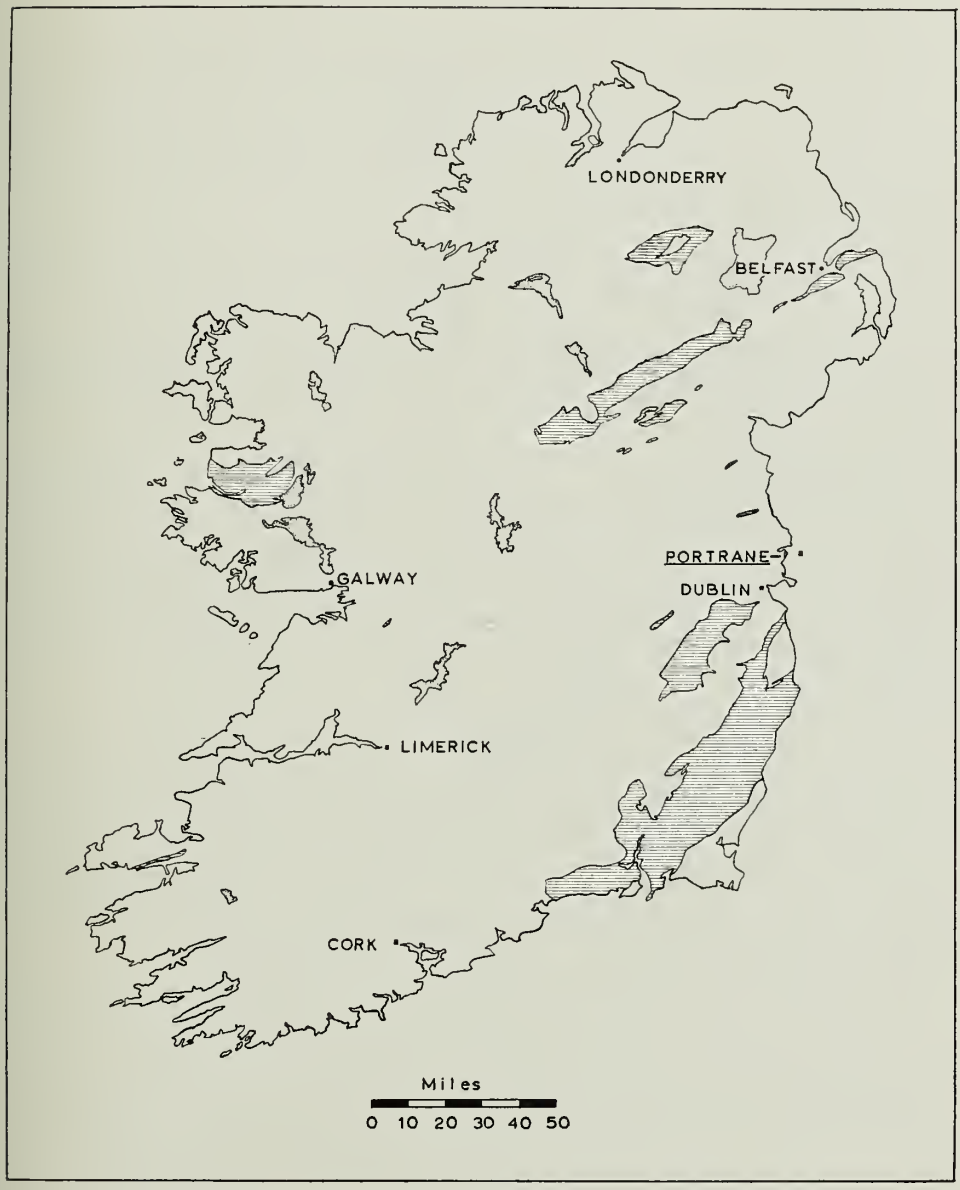

FIG. 1. Map of Ireland to show the situation of the Portrane Inlier relative to the other outcrops of Ordovician rocks (shaded).

horizons were described by Reed in the appendix to this paper. Their largest fauna was obtained from the massive limestone, which, as stated by Harper (1948 : 57), is in the middle of the limestone sequence, with thinly bedded limestones and shales

both above and below. At the time of their investigation a small quarry had just been opened in the massive limestone at the top of a cliff (Gardiner & Reynolds, 1897 : 529, pl. 43, locality " C "), and it was this quarry which yielded to them nineteen trilobites, one ostracod and nine brachiopod species. In commenting on the fauna Reed (1897 : 537) noted that the brachiopods " on the whole seem to be far from common ". For the limestone bands below the massive limestone the fauna, according to Reed, consists dominantly of poorly preserved corals, only one trilobite being included in his list (p. 538).

The paucity of brachiopods in Reed's list is surprising, particularly as Baily records the presence of sixteen species of this phylum, and Cole (1892 : 34) says " here at Portraine brachiopod life is at once seen to be abundant ".

Since 1897 contributions on the structure of the inlier have been made by Lamont (1938), Shackleton & Harper (1940), whilst Professor J. C. Brindley and Mr. B. Connor of University College, Dublin are currently investigating this aspect of the geology.

Contributions on the age of the limestone have been made by Lamont (1938 : 9 ; 1941 : 455), Stubblefield (1939 : 61), the various opinions being summarised by Harper (1948 : 57). These interpretations of the age of the limestone vary between late Caradocian to early Ashgillian. More recently Dean (1961 : 124) has suggested the possibility of a Pusgillian age for the Portrane Limestone. The suggested ages have, however, been based principally on one or two trilobite species, rather than an assemblage ; with the large and varied assemblage now available it is hoped to provide conclusive evidence of its age.

III. THE FAUNA—PRESERVATION AND LOCATION

One feature that has been noted by all who have commented on the Portrane Limestone is that the thinly bedded limestones under the massive limestone contain abundant corals which have been weathered out by the sea. Before the turn of the century it was realised that this occurred because the corals (and the other fossils) had been silicified (Cole, 1892 : 33 ; Sollas, 1895 : 101), but until the current investigation no use of this knowledge had been made to try to obtain a fauna, although etching techniques have now been in use for some years.

The limestone from which the present fauna has been etched is found in this series of thinly bedded limestones and shales, that is, the one beneath the massive limestone. The localities which have proved so profitable are to be found on either side of a small bay immediately to the south-west of the old lime kiln (see Text-fig. 2). At the top of the cliff on the north-east side of the bay is the base of the massive grey limestone ; beneath it are thinly bedded dark limestone bands (about 7 cm. thick) which alternate with black shales. The limestones of this part of the sequence are usually devoid of fossils, and the beds (about $5\frac{1}{2}$ metres in thickness) show considerable contortion. Beneath these is a band of dark limestone attaining a maximum thickness of 35 cm. This is the highest of the richly fossiliferous horizons from which material was etched, being fossiliferous for a distance of over 10 metres laterally along the cliff. Underlying this are a further 60 cm. of the thin bedded limestone-shale alternations, and then $1\frac{1}{2}$ metres of highly fossiliferous

limestone, the bands varying from 5 to 23 cm. in thickness, and separated by thin shaly partings ; these limestone bands yielded the bulk of the fauna at this locality.

The same horizon can be traced on the south-west side of the bay where it has also yielded a large fauna ; further along the coast to the south-west more material has been obtained from this horizon, but here it is by no means so rich in fossils.

The etching of the material was carried out using dilute acetic acid in preference

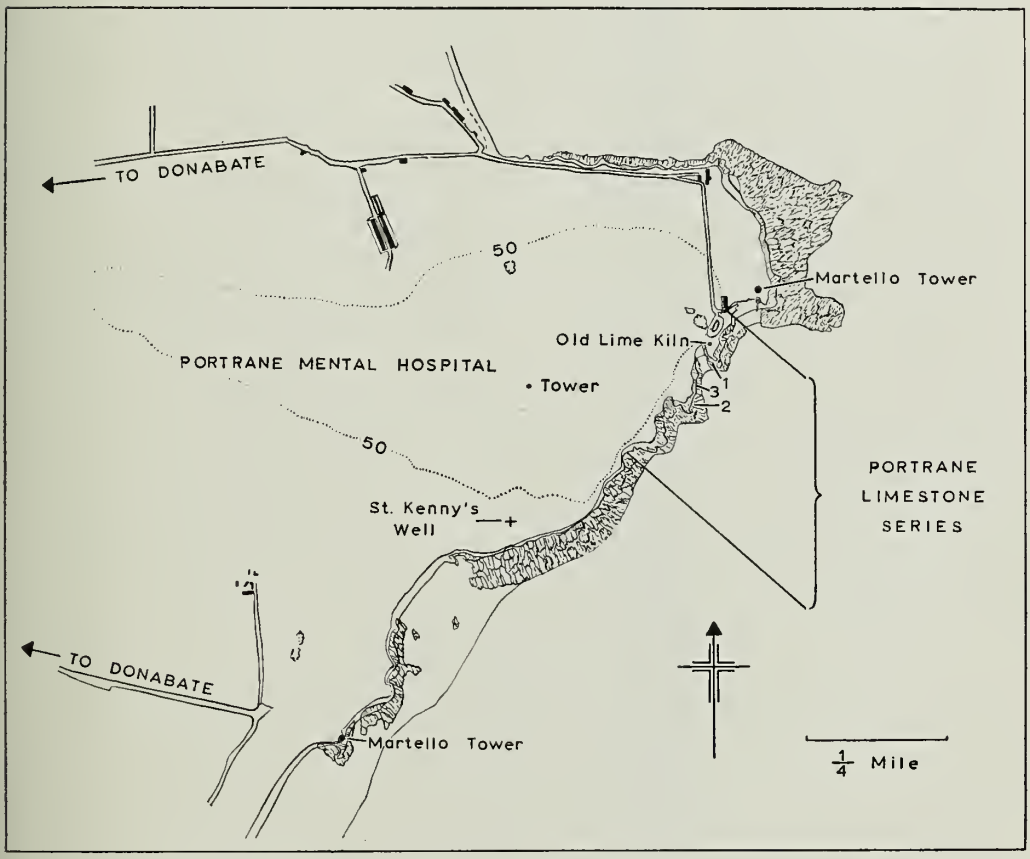

FIG. 2. Sketch-map of the coastline at Portrane, showing the three most fossiliferous localities of the Limestone series. Apart from the continuous outcrop indicated, smaller outcrops occur immediately east of the north Martello Tower, and at the edges of the strand south-west of St. Kenny's Well.

to hydrochloric acid (Bell, 1948) as the latter would have been harmful to the inarticulate brachiopods. Although the etching was consequently a much slower process, the fact, that fifteen genera of these interesting little shells have been recovered more than compensates for the additional time involved.

The actual silicification itself presents problems ; in the first place the silicification

is not always complete, so that some specimens are lost or badly eaten away during etching ; secondly the coarseness of the silicification is also variable. The corals, as already stated by Reed (1897 : 538), are in a very inferior state of preservation as a result of the imperfect silicification ; preservation of the brachiopods varies,

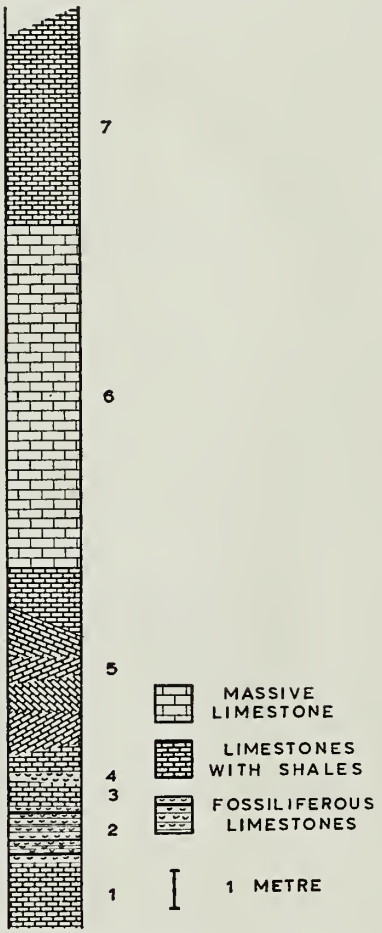

FIG. 3. The Upper Ordovician Limestone sequence of the Portrane Inlier : (1) the lowest thinly-bedded limestone—shale sequence in Lime Kiln Bay, base not seen ; (2) highly fossiliferous limestone bands with thin shale partings ; (3) unfossiliferous limestone and shales ; (4) the highest and thickest limestone band from which a fauna was etched ; (5) highly contorted thinly bedded limestones and shales, very poorly fossiliferous ; (6) pale massive limestone ; (7) upper thinly bedded limestones and shales, an unknown thickness being cut out by faulting.

sometimes they show large coarse rings of beekite, sometimes they are preserved down to the finest details.

The stratigraphy of the inlier as a whole is being investigated by the writer and

will be described elsewhere ; this present series of papers is concerned with the description of the first silicified Upper Ordovician fauna recorded from the British Isles.

IV. THE INARTICULATE BRACHIOPODS

Fifteen genera of inarticulate brachiopods are described in the following systematic account and include one new genus and eight new species. Other specimens, which evidently do not belong to any known species, are only represented either as an odd valve or broken fragments. The erection of new species for these forms is not justified on the present material. Certain other etched fragments are too fragmentary for identification or description ; this is the case with " lingulid " fragments in particular. Accordingly these scraps have been retained by the writer pending further material of a more complete nature being recovered from future etchings.

The inarticulates have little to contribute towards establishing the horizon of the limestone, due to the fact that Upper Ordovician forms from other regions are insufficiently known and close comparisons cannot be made. Large scale acetic acid etching has been used on silicified limestones of Cambrian and Middle Ordovician ages (Palmer, 1955 ; Cooper, 1956) ; but not on Upper Ordovician rocks prior to the present investigation.

Of the genera present at Portrane, the only known species of the new genus *Rowellella* is from the Portrane Limestone itself. *Lingulella* is ubiquitous, whilst the genera *Paterula, Multispinula, Orbiculoidea, Schizotreta* and *Trematis* are widespread, being recorded from the British Isles, Europe, America and in some cases North Africa. *Paterula* is generally a rather rare form. The occurrence of *Multispinula* is probably rather high for this genus, which was erected by Rowell (1962) to embrace Middle Ordovician species previously referred to *Schizambon.* Reed (1917) has however recorded the genus from the Drummuck Group (Starfish Bed) at Girvan.

Six genera, previously unknown outside North America, occur at Portrane :— *Leptobolus, Acanthambonia, Eoconulus, Spondylotreta, Ephippelasma* and *Scaphelasma.* Whilst *Leptobolus* ranges from Trenton to Cincinnatian, the remainder are Middle Ordovician forms and all occur in the Pratt Ferry Formation of Alabama, the last two not being recorded outside this particular horizon. Cooper (1956) also obtained a large and varied etched inarticulate fauna, but this should not be taken as indicating close stratigraphical relationship between the Pratt Ferry and the Portrane fauna. It does, however, serve to impress the fact that many inarticulates, which might prove to be useful stratigraphically if sufficient of them could be obtained, must be present in other Ordovician limestones.

Whilst *Spondylotreta* has not previously been recorded from Europe, it may well be that specimens at present masquerading under the names of *Conotreta* and *Acrotreta* actually belong to Cooper's genus.

Of the two remaining genera, *Acanthocrania* and *Philhedrella,* neither has been recorded from the British Isles. The former has a very long range in North America, and occurs in the Estonian Ordovician. *Philhedrella* has apparently been found only in eastern Europe, in the Baltic Ordovician and in the Polish Silurian ; unfor-

tunately there is some uncertainty about this genus as the type species is inadequately known.

The only inarticulate species from Portrane which is undoubtedly conspecific with a described form is *Orbiculoidea shallochensis* Reed, known from the Whitehouse Group at Girvan.

In conclusion, I should like to express my thanks to Dr. A. J. Rowell of Nottingham University for reading and constructively criticising the manuscript, and also to Professor A. Williams for granting me access to his data on the Girvan brachiopods, which had not been published by the time this work was completed.

V. SYSTEMATIC DESCRIPTIONS

Superfamily **OBOLACEA** King

Family **OBOLIDAE** King

Subfamily **LINGULELLINAE** Schuchert

Genus ***LINGULELLA*** Salter, 1866

Lingulella sp. 1

(Pl. 1, figs. 1–4)

Description. The two dorsal valves here placed are small for the genus, and of narrowly oval outline, tapering sharply both anteriorly and posteriorly. Profile gently and evenly convex with maximum width (almost two-thirds of the valve length) at about mid-valve. Ornament of concentric growth lines of variable strength, rather poorly preserved.

Interior with a small apical plate ; muscle field about a quarter of the valve length, slightly thickened and of roundedly triangular outline with its front edge convex anteriorly. Differentiation of the muscle field not pronounced. Valve floor anterior to the muscle field traversed by fine, radiating pallial impressions.

Dimensions. BB. 28219 : length 2·7 mm., width 1·4 mm. BB. 28220 : width 1·4 mm.

Lingulella sp. 2

(Pl. 1, figs. 5, 6)

One dorsal valve and some fragments of this genus resemble *Lingulella* sp. 1 in outline and in the poorly preserved nature of the ornament, the fine concentric growth lines only being clearly seen on one fragment. The complete valve is slightly deeper than in *Lingulella* sp. 1, but the main difference is seen in the muscle field. This is thicker, with the anterior edge straight, and is further divided longitudinally into three sectors, with the median sector depressed below the lateral ones. The presence of a weak median ridge on the valve floor anterior to the muscle field also differentiates the two species. Width of dorsal valve (BB. 28221) 1·1 mm.

Lingulella sp. 3

(Pl. 1, figs. 7, 13)

The posterior fragment of a ventral valve (BB. 28222) much larger than the above species shows a pair of well-defined propareas divided by a pedicle groove. The muscle impressions on the valve floor are very faint and show no thickening ; the anterior edge of the field appears to be quite straight. Ornament poorly preserved, but one side of the valve shows fine growth lines with a coarser concentric line developed at regular intervals.

Discussion. From the above descriptions, it will be quite clear that species 1 and 2 are quite distinct ; the problem is whether sp. 3, represented by a ventral valve, is conspecific with sp. 1. At first sight, the regular development of the stronger concentric lines in sp. 3 appears quite distinctive from that of sp. 1. However, Cooper (1956 : 206) describes a species from the " Ottosee formation " of Virginia, *Lingulella virginiensis*, which possesses a similar ornament to *Lingulella* sp. 3. Cooper's figured specimen (pl. 1, C, figs. 4, 5) shows, as stated in his plate description (p. 1025), a difference in the ornamentation of each valve. That of the ventral valve is similar to *Lingulella* sp. 3 and that of the dorsal similar to *Lingulella* sp. 1.

Accordingly it may well be that the specimen here referred to as *Lingulella* sp. 3 is in fact the ventral fragment of a large specimen of species 1 or even species 2, the ornament of the latter being too badly preserved to justify a decision either way.

Other fragments of " lingulids " have been recovered from the etchings but in the absence of a distinctive ornament and the all important posterior margin, it is quite impossible to place such fragments in the correct subfamily, let alone genus or species.

Subfamily **ACANTHAMBONIINAE** Cooper

Genus *ACANTHAMBONIA* Cooper, 1956

Acanthambonia portranensis sp. nov.

(Pl. 1, figs. 29–31)

Diagnosis. Ventral valve of subcircular outline, evenly convex in transverse profile ; longitudinal profile strongly convex posteriorly, only gently so anteriorly. Shallow but distinct sulcus developed. Surface, including posterior margin, covered with fine hair-like spines and faint concentric growth lines. Beak small ; propareas narrow, separated by small pedicle groove thickened into a shallow plate internally at the apex.

Muscle scars not well defined posteriorly, but two very clear sub-oval adductor scars (0·3 mm. long in holotype) situated at about mid-valve ; at antero-median extremity of each, and protruding slightly towards mid-valve, is a tiny scar which forms an apparently separate part of the muscle field.

Dorsal valve gently convex ; inner surface with two narrow submedian grooves, diverging slightly and extending to margin. Posteriorly these grooves (*vascula*

media?) are flanked by poorly-defined muscle fields, present as depressed areas and traversed by further radial grooves.

HOLOTYPE. Ventral valve (BB. 29860) : 1·5 mm. long, 1·7 mm. wide.

PARATYPES. Ventral valve (BB. 29861) : 1·2 mm. long, 1·3 mm wide. Two broken valves, one ventral (BB. 29862) and the other dorsal (BB. 29863).

DISCUSSION. The new species differs from the two Porterfield species of Cooper, *A. minutissima* and *A. virginiensis*, in having a ventral instead of dorsal sulcus ; and in having clearly impressed ventral adductor scars. Although the dorsal valve here described is incomplete, the impressions of the interior compare closely with those of *A. minutissima* (Cooper, 1956, pl. 18, D, fig. 23).

Subfamily **GLOSSELLINAE** Cooper

Genus ***LEPTOBOLUS*** Hall, 1871

Leptobolus rarus sp. nov.

(Pl. 2, figs. 1, 2)

DIAGNOSIS. *Leptobolus* possessing both radial and concentric ornament ; ventral interior with strong ridge extending anterior to pedicle groove, branching as a " U " fork. Two submedian round muscle pits developed anterior to main lateral scars.

HOLOTYPE. Incomplete ventral valve (BB. 28229), 1·3 mm. long.

DESCRIPTION. Ventral valve small, gently convex, of sub-oval outline. Ornament not seen umbonally, anteriorly consisting of fine concentric growth lines, with stronger ones at intervals, and lightly impressed radial ribs. Very fine radiating lines superimposed over the whole surface. Interior with well developed propareas and a moderately deeply impressed pedicle groove, from which the stout internal median ridge extends anteriorly. This thick ridge terminates at about half the length of the muscle field, a pair of finer ridges developing from its outer sides. These diverge slightly and enclose a sub-oval median muscle scar, and then are deflected laterally to form the anterior margin of the main muscle area. Anterior to the point of deflection a pair of smaller rounded pits are developed between the ridges and the median scar. Anterior to the muscle scars, the punctate nature of the inner surface is clearly seen ; two radial ridges on one side of the valve are attributed to vascular origins.

Dorsal valve unknown.

DISCUSSION. This genus was previously unknown in Europe, occurring only in North America, principally in rocks of Trenton-Cincinnatian age (see Foerste, 1924 : 107), although Ruedemann (1901 : 569) records an older species from the Normanskill Shale. This is a black graptolitic shale which contains only two other brachiopods, *Paterula* and *Schizotreta*, both of which are present at Portrane. Cooper (1956 : 214) also records two species from the Edinburg Formation that may probably be referred to *Leptobolus*.

The Portrane form, although only present as a broken ventral valve, is considered to be sufficiently distinctive to warrant the erection of a new species. The only

other species possessing a radial ornament is *L. insignis* Hall, but this lacks the strong ridge in front of the pedicle groove, has a " V " shaped fork, and does not show the small, round and deeply impressed muscle pits anterior to the main scars as in *Leptobolus rarus*.

Genus ***ROWELLELLA*** nov.

Diagnosis. Small, dorsi-biconvex, elongate sub-rectangular shells with minute marginal beaks. Direction of shell growth alters after young stages so that shell increments are added laterally at right angles to original growth direction, deepening the valve and giving a geniculate appearance to sides of valves in transverse profile. Growth of dorsal valve depressed ventrally along front margin giving a variably developed geniculation to valve, emphasising its convexity. Ornament of somewhat strong, irregular concentric lamellae.

Ventral interior with median thickening posteriorly. Dorsal interior without apical plate ; muscle field only known at its anterior end, where a low median ridge separating the scars joins a stronger transverse " W " shaped ridge bounding the field anteriorly. Two sub-parallel or bowing grooves of *vascula media* extend forward from this ridge.

Discussion. The new genus resembles *Pachyglossella* Cooper (1960 : 601), [= *Pachyglossa* Cooper, 1956, *non*. Hodgson, 1843, *non* Fauvel, 1868] in the convex dorsal valve and similar ornament, but differs in the sub-parallel and geniculated lateral margins, while the strong convexity also separates the genus from other obolids, for example *Lingulella*. The features of the dorsal interior are not well known for *Pachyglossella*, hence a comparison cannot be made with *Rowellella*.

The lack of an apical plate in the dorsal valve suggests that the genus belongs to the Glossellinae rather than the Lingulellinae. Only one young specimen shows the structure of the posterior margin of the dorsal valve, and so there is the possibility that the structure is absent because of the youth of the shell.

Apart from two complete young shells, the specimens of the type species all appear to be dorsal valves, with the posterior region invariably broken. The absence of ventral valves may be due to cementation, but as no scars are seen on the complete valves, it would seem more likely that the ventral valves were simply very thin and accordingly easily destroyed. Very thin shell may also account for the absence of the dorsal posterior ; the valves thin out posterior to the ridge at the anterior end of the muscle scars in the broken valves, whilst the shell of the young forms is also very thin compared with the thick shell of later growth stages as seen in the larger fragments.

Type species. *Rowellella minuta* sp. nov.

Rowellella minuta sp. nov.

(Pl. 1, figs. 8–12, 14–28)

Diagnosis. Small dorsi-biconvex valves of elongate outline, anterior and posterior margins evenly rounded, lateral margins sub-parallel. Lateral margins deflected

towards opposite valve producing a lateral geniculation, accompanied by ventral deflection of dorsal anterior margin and less pronounced reflection of ventral valve. Ornament of strong concentric lamellae only, densities of 12, 12 and 14 per mm. being taken on three specimens.

Ventral interior shows posterior median thickening. Dorsal interior without apical plate. Muscle scars of posterior region of body unknown ; anteriorly a low ridge generally divides muscle field into two areas, but in two specimens ridge depressed medianly, indicating that muscles were probably attached in central region also. The ridge terminates against a thickened transverse " W " shaped ridge bounding muscle field anteriorly. From the two anterior points of the " W ", two grooves of *vascula media* extend anteriorly either sub-parallel or bowed slightly outwards. Fine, light grooving at anterior margin indicates presence of *vascula terminalia.*

	Length	*Width*	*Thickness*
Holotype. Complete shell (BB. 28223) .	1·0 mm.	0·45 mm.	0·25 mm.
Paratypes. Complete shell (BB. 28224) .	1·2 mm.	0·6 mm.	0·25 mm.
Incomplete dorsal valve (BB. 28225) .	—	0·65 mm.	—
Incomplete dorsal valve (BB. 28226) .	—	0·75 mm.	—
Incomplete dorsal valve (BB. 28227) .	—	1·15 mm.	—
Incomplete dorsal valve (BB. 28228) .	—	1·3 mm.	—

Discussion. Due to the broken nature of the posterior margin, no measurements (width excepted) can be taken on the sample except in the case of the two complete shells. These are young shells, but the older shells are still very small, the maximum width recorded being 1·4 mm., whilst the longest shell (broken posteriorly) measures 1·8 mm. The broken posterior margin also prevents an accurate density for the growth lamellae being given, as there can be no control on the position of measurement. This is very important when giving an accurate statistical assessment of the character, as the lamellae vary according to their position, becoming coarser with the increased size of the shell.

Little is known of the ventral interior, the thickening of the posterior region being observed through the exterior of the shell.

Superfamily **TRIMERELLACEA** Davidson & King

Family **PATERULIDAE** Cooper

Genus ***PATERULA*** Barrande, 1879

Little was known about the interior of this rather rare genus until Cooper (1956 : 236) described some well preserved etched specimens, in particular *P. perfecta* from the Pratt Ferry formation. Some of the Portrane shells are equally well preserved, and enable Cooper's description of the valve interiors to be enlarged upon ; unfortunately these shells are exceedingly fragile, to the extent that only one ventral valve possesses the flattened marginal rim in its entirety. Thus it is not possible to obtain length and width measurements for the valves to compare directly with those

of Williams (1962 : 88) for *P. balclatchiensis* (Davidson). Measurements of length and width have been taken on the thickened inner edge of the marginal rim to obtain a statistic for " shell outline " ; obviously this does not represent a growth line of the shell, but it does give a certain indication of outline for this material.

In the interior of the ventral valve, the present writer regards the whole thickened area of the valve floor posterior and posterolateral to the central scar as constituting the ventral muscle field. The central scar, which is situated at the anterior end of the two slightly divergent impressed grooves arising just in front of the pedicle groove, is pear-shaped rather than circular, with a definite apex at the anterior end. Posterolateral to the central scar is a pair of rounded pits which in some cases seem to be confluent with the smaller anterolateral pair, all being regarded as seats of muscle attachment. The thickened areas posterolateral to the impressed lines form the bulk of the muscle field, with a pair of impressed scars on the lateral edges, and a pair of umbonal scars at the posterior edge. Encircling the muscle field anteriorly are numerous pallial impressions which radiate outwards across the valve floor.

In the dorsal valve the muscle field is large and bluntly sagittate in outline. Posteriorly the deeply inserted umbonal muscle scars are divisible into two ; anterolateral to these another pair of triangular pits occurs at the edge of the muscle field. The anterolateral pallial trunks of Cooper are regarded as being anterolateral extensions of the muscle field ; the grooves developing at their edge, and passing on to the valve floor, are certainly pallial sinus impressions. The median tongue of the muscle field shows two pairs of small scars, one situated laterally near the posterior end, the other half way along the tongue. A pair of pallial sinus grooves develops from the median anterior margin of this part of the muscle field.

Paterula cf. *perfecta* Cooper

(Pl. 2, figs. 3–5, 8–10, 13, 16)

1956. *Paterula perfecta* Cooper, p. 238, pl. 18H, figs. 54–56, pl. 24D, figs. 12–23.

Description. Small dorsibiconvex shells ; ventral valve very gently convex, about one tenth as deep as long ; dorsal valve about one sixth as deep as long, but ranging up to a quarter in larger valves. Outline sub-oval to sub-circular. Umbones of both valves sub-marginal ; ornament of fine concentric growth lines. Valve interiors with a peripheral rim and a clearly defined pedicle groove and notch in the ventral valve. Muscle and pallial impressions as described above.

Discussion. The species nearest to the Portrane shells are *Paterula perfecta* Cooper, *P polita* Cooper and *P. balclatchiensis* (Davidson). Internally, allowing for preservation, the Portrane shell cannot be differentiated from *P. perfecta* ; unfortunately the interiors of the other species are not known.

Cooper (1956) distinguishes *P. polita* from *P. perfecta* by its smaller size, more oval outline and less convex profile in both valves, and also by its smaller pedicle opening. Text-fig. 4 is a graph showing valve thickness against length for ventral and dorsal valves from Portrane, together with the paratypes of *P. perfecta* (dorsal and ventral) and *P. polita* (dorsal only).

Although only a solitary reading is available for the American shells, and the measurements are given to the nearest 0·05 mm., the following points are noted :

1. The Portrane valves vary over the size range of both *P. polita* and *P. perfecta*.

2. The dorsal valve of *P. perfecta* paratype has identical measurements with a Portrane valve.

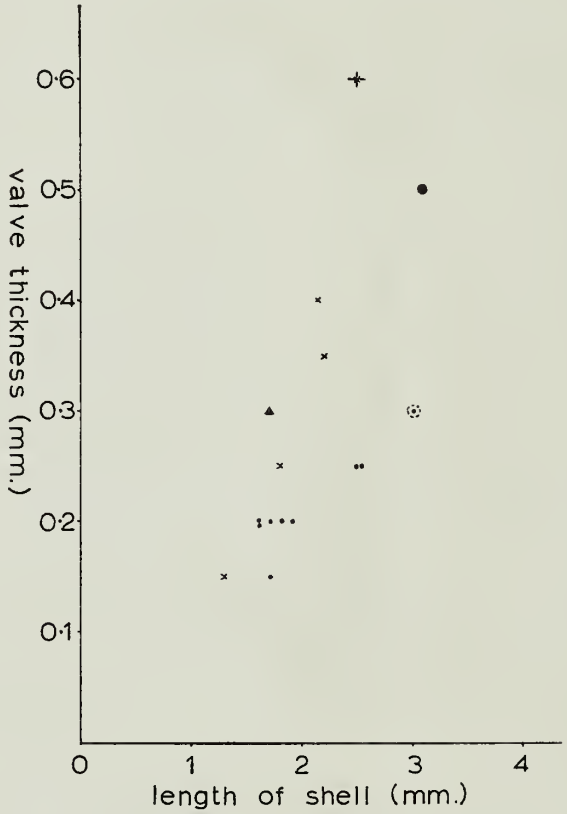

FIG. 4. Graph showing the relationship of valve thickness to length in dorsal and ventral valves of *Paterula*. X—Portrane dorsal valves ; ·—Portrane ventral valves ; ●—ventral paratype of *P. perfecta* ; +—dorsal paratype of *P. perfecta* ; ▲—dorsal paratype of *P. polita*. The Portrane ventral valve whose length is approximate is enclosed by a broken line.

3. The plots of the Portrane dorsal valves lie on a curve, suggesting allometric growth, with larger valves relatively thicker than smaller ones.

4. The dorsal valve of *P. polita* falls within the scatter of this curve.

5. The gradient for the Portrane ventral valves is very much less than for the dorsal ones, indicating that they are less convex ; a comparison with the solitary valve of *P. perfecta* shows the latter to be much deeper. The Portrane

valve of comparable size is the largest from the locality and is broken anteriorly ; the thickness is 0·3 mm., the length c. 3·0 mm., but may be slightly longer.

From the above it would appear that, first, on actual size, and convexity of the dorsal valve, there is little justification for separating the three forms ; and secondly, the ventral valve is deeper for *P. perfecta* than for the Portrane shells. Unfortunately, the samples are too small to indicate whether this is statistically significant or not.

The width : length ratio for the solitary Portrane ventral valve whose peripheral rim is sufficiently well preserved for measurement, is 80% : measurements on the inner rim for eight valves give ratios of 80, 82, 87, 88, 89, 92, 93, 97%, the mean (and variance) for these figures being 88·5% (31·7). Thus, even using this statistic as indicating outline, there is considerable variation. Measurements taken from Cooper's figures for this statistic give 91, 91, 94, 95, 97%. Comparison by Rank Sum Test shows no significant difference between the two sets of shells.

No figures are available for this statistic for the Balclatchie shells. For the true valve outline Williams (1962) gives 96·4% (var. 35·2) as the ratio for 11 valves ; a direct comparison of this with the " outline statistic " for the Portrane valves by a " T " test shows a significant difference ($0{\cdot}01 > p > 0{\cdot}001$) ; whilst such a comparison is not strictly valid it certainly indicates the rounder outline of the Balclatchie shells.

With the evidence available the Portrane shells are placed close to *P. perfecta*, probably differing only in the flatter ventral valve. *P. polita* is very likely also conspecific with *P. perfecta*.

Superfamily **ACROTRETACEA** Schuchert

Family **ACROTRETIDAE** Schuchert

Subfamily **ACROTRETINAE** Schuchert

Genus ***SPONDYLOTRETA*** Cooper, 1956

This acrotretinid is characterised by the presence of a strong median septum in the ventral valve supporting a spoon-shaped structure at the apex, which in life bears the pedicle. The posterior edges of the structure continue along the inside of the pseudointerarea towards the commissure as a pair of divergent ridges.

Cooper remarks (1956 : 255) that the strong median septum has a similar function to the antero-apical callosity of *Conotreta* ; and indeed it appears rather difficult to distinguish between the two when the median septum of *Spondylotreta* is not so well developed, or when the callosity of *Conotreta* is well developed. This is brought out by figures of an internal cast of *Conotreta davidsoni* (Williams, 1962, pl. 7, figs. 1–3), which show the apex divided into three, indicating an arrangement not very far removed from that of *Spondylotreta*.

Some uncertainty also exists over the dorsal valve of this genus, the ornament being the principal basis for assignment of a solitary concave valve to the type species, *S. concentrica* Cooper.

TYPE SPECIES. *Spondylotreta concentrica* Cooper (1956 : 255).

Spondylotreta parva sp. nov.

(Pl. 2, figs. 17, 20–25 ; Pl. 3, figs. 1, 5, 9, 15)

Diagnosis. Small *Spondylotreta* of sub-circular outline ; ornament of fine concentric growth lines continuous across pseudointerarea. Ventral valve conical, with raised median track along pseudointerarea. Dorsal valve flat with shallow median sulcus ; dorsal interior with triangular median septum occupying middle half of valve, apex of septum within anterior third of its length ; posterolateral muscle field large.

	Length	*Width*	*Height*
Holotype. Ventral valve (BB. 29871) .	1·15 mm.	1·4 mm.	1·1 mm.
Paratypes. Dorsal valve (BB. 29872) .	1·3 mm.	—	—
Dorsal valve (BB. 29873) . . .	1·4 mm.	1·5 mm.	—
Ventral valve (BB. 29874) . . .	1·4 mm.	—	c. 1·4 mm.

Unfigured paratypes BB. 29875–76.

Description. Posterior of conical ventral valve flattened due to the broad pseudointerarea whose elevated median track shows no sign of an intertrough ; foramen minute, slightly post-apical. Mean apical angle in longitudinal profile for nine valves was 79° (var. 74°) ; for the same valves the mean transverse apical angle was 87° (var. 95°). The mean height of the cones, measured perpendicularly to the plane of commissure, for seven valves was 75·5% of the valve length (var. 183·6%). The mean ratio of length : width at the commissure for eight valves was 91% (var. 72%).

For the outline of ten dorsal valves a mean length : width ratio of 96·5% (var. 37·4) was recorded, the straighter posterior margin of an otherwise round outline being broken medianly by the small protruding beak. The almost flat profile of this valve is modified by a convex umbonal region and a narrow groove or sulcus developed anteriorly.

The density of the concentric ornament varies according to position of measurement on the shell (p. 234). However, 30, 31 and 33 concentric ridges per millimetre were recorded for one ventral and two dorsal valves respectively.

In the ventral interior, the median septum is formed from a pair of closely opposed parallel plates on the anterior wall, and extends about half way to the commissure. Apically the plates are high, extending to the middle of the valve to unite with a vertical column extending dorsally from the apex. Two divergent plates develop from this column to form a pedicle chamber in the posterior part of the apex. A pair of apical pits (Palmer, 1955 : 768) is situated on the posterior surface at the ends of the pedicle chamber. On the anterolateral surfaces of each side of the apical structure are three simple pallial sinuses ; towards the commissure the interior is covered with fine radial lines which are the *vascula terminalia* produced by branching of the main canals.

In the dorsal interior is a triangular median groove posteriorly, bounded laterally by small concave propareas, the inner edges of which are thickened into ventrally projecting eminences. Around the remainder of the valve is a more or less well

defined flat, slightly thickened marginal band or rim. In front of the posterior groove is a subrectangular depression corresponding to the platform of *Conotreta*. Rising anterolaterally from this is a pair of divergent ridges which form the inner edges of a pair of small but clearly impressed areas, probably for muscle attachment. Anterolateral to these is a pair of larger, shallowly impressed sub-elliptical muscle scars, which are bounded on the inside by a low medianly deflected continuation of the divergent ridges and on the outside by the rim. The strong median septum rises gently from the anterior end of the " platform ", reaching a sharp point near its front end, then falling sharply to the valve floor.

The mean length from the umbo to the anterior end of the median septum relative to the valve length for ten specimens was 73·6% (var. 15·6) ; the mean length from the umbo to the maximum height of the median septum relative to valve length for six specimens was 57·3% (var. 23·9) ; and the mean length of the valve posterior to the median septum to valve length for nine valves was 23·7% (var. 9·95).

Discussion. The size of these shells is very small ; the mean length recorded for eight ventral valves was 1·27 mm. (var. 0·22), and for ten dorsal valves 1·15 mm. (var 0·33). Considering all features of the shells (numbers, size, outline, ornament, etc.) it is evident that the two valves belong together, a factor which is not always clear when working with etched material. These shells are placed in this genus on the basis of the internal structure of the ventral valves, which is rather variably developed in the species, the septa sometimes only being seen as a dark " Y " in the apex of the valve when held up to the light. The large posterolateral muscle field of the dorsal valves agrees with that figured by Cooper (1956) for his type species, confirming the placing of his dorsal valve with the ventral valves of the genus, and further separating the genus from *Conotreta*.

The new species differs from the type species. *S. concentrica*, in having a pronounced median ridge along the pseudointerarea, less developed septa in the ventral interior (which may be accounted for by the smaller size) and a well developed depression anterior to the posterior median groove of the dorsal interior. The only other species at present referred to this genus is *S.? declivis* (Willard) whose interior is unknown. Its ventral valve differs from *S. parva* in having a concave posterior slope with a well defined intertrough.

Spondylotreta cf. ***parva***

(Pl. 2, figs. 11, 12, 14, 15, 18, 19)

Apart from the small delicate *S. parva*, fragmentary specimens of larger, thicker shells (BB. 29877–81) are also present. A strong median ridge in the ventral fragments appears to have supported a spoon-shaped structure umbonally, as in *S. parva* ; the pallial markings are much more pronounced but again show a simple pattern.

The dorsal fragments resemble *S. parva* especially in the disposition of the posterolateral muscle scars, but differ in the generally more transverse outline, together with much wider and more substantial propareas, separated only by a weakly developed median groove. Anterior to this, the platform is a thickened area, whilst

the median septum appears to have its maximum development at its posterior end.

It would appear that many of these features are merely the result of thickening, and are thus large forms of *S. parva* ; but a specimen of comparable size to *S. parva* (*c.* 1·2 mm.) shows the transverse outline (the specimen is broken but a length : width ratio on a growth line is 75%) and the contrasting proparea development.

In view of the fragmentary nature of these shells they are placed as *S.* cf. *parva* ; complete material is necessary before the variation of shell outline can be put in perspective, and the problem would be simplified by the recovery of shells showing continuous size variation between the small *S. parva* and the larger shells (the largest incomplete specimen is over 4·0 mm. long).

Genus ***EPHIPPELASMA*** Cooper, 1956

Ephippelasma ? sp.

(Pl. 3, figs. 2, 6, 10, 14)

Description. Ventral valve minute, of elongatedly conical profile with the apex curved posteriorly, apical angle about 40°. Foramen circular, minute, situated just posterior to the umbo. Outline of commissure transversely elliptical with straight anterior and posterior margins. Pseudointerarea wide, poorly preserved, concave in profile ; very slight tendency for a sulcus on the anterior surface of the shell. Ornament of concentric growth lines ; valve interior obliterated. Dorsal valve unknown.

Dimensions. BB. 29882 : length 0·55 mm., width 0·8 mm., height 0·6 mm.

Discussion. A solitary ventral valve is quite different from the other acrotretinids here described in its valve profile, concave pseudointerarea, and in the elliptical outline of the commissure. The closest known acrotretinid to this valve is *Ephippelasma minutum* Cooper, whose ventral valve appears to differ only in having a slightly narrower transverse apical angle, and in not having such a narrowly elliptical valve outline, which is a specific character of the Portrane shell.

The genus is characterised by the extravagant development of a saddle-shaped plate in the dorsal valve, whose height is 0·6 mm. in the dorsal paratype of *E. minutum*, a valve itself only 0·6 mm. long. Unfortunately, no comparable dorsal valve was found in the Portrane material to confirm the placing of the ventral valve in this genus.

Genus ***SCAPHELASMA*** Cooper, 1956

Scaphelasma ? sp.

(Pl. 2, figs. 6, 7)

One small acrotretinid dorsal valve (BB. 29883 ; length 0·6 mm., width 0·8 mm.) appears to belong to this genus. The ornament differs strikingly from that of other members of the subfamily here described, consisting of fine concentric growth lines posteriorly, which pass sharply into very coarse concentric lamellae anteriorly.

The valve is of transversely elliptical outline, convex umbonally, becoming flat

and developing a shallow median sulcus, with convex rims anterolaterally. Valve interior with a short low median septum occupying the middle third of the valve, rising gently towards its anterior end, where a slightly thickened ridge following the shell outline crosses the valve floor. This ridge encloses a pair of sub-reniform muscle scars at its posterolateral extremities. Propareas small, with tooth-like eminences on either side of a median groove which has a thickened anterior margin forming a tiny " shelf ". A hollow on the valve floor separates this from the median septum.

The specimen is placed in the genus *Scaphelasma* on the nature of the ornament, and to a lesser extent on outline, profile and valve interior. The " shelf " is somewhat less prominent than that figured by Cooper for *S. septatum* (1956, pl. 18, J) and the septum much lower ; neither does the septum reach the anterior margin. These differences, however, may be accounted for by the much smaller size of the Portrane shell. A comparison with the figured exterior of the type, and only, species of *Scaphelasma* from the Pratt Ferry formation shows that the coarse ornament develops very much earlier in the Portrane shell, at about 0·45 mm. instead of 0·75 mm.

Whilst in such a small valve the generalised features of the interior may equally well indicate a *Conotreta*, no species of *Conotreta* possesses this kind of ornament. The possible exception to this is *Conotreta* ? *concentrica* Cooper whose dorsal valve is not known, but which may represent a new genus in Cooper's opinion (1956 : 250).

The dorsal valve of *Rhysotreta* also shows several similarities to the Portrane shell, especially in the ornament, but is quite distinct in the development of its interior.

Superfamily **SIPHONOTRETACEA** Kutorga

Family **SIPHONOTRETIDAE** Kutorga

Genus ***MULTISPINULA*** Rowell, 1962

Multispinula sp. 1

(Pl. 3, figs. 22, 23)

One incomplete ventral valve (BB. 29897) and two shell fragments (BB. 29898) are ascribed to this species.

Description. Ventral fragment 1·1 mm. long, evenly convex with a slightly procline pseudointerarea. Foramen 0·7 mm. long, almost triangular with straight sides and a slightly irregular anterior edge ; posterior part filled by a concave plate situated below the valve surface. Ornament of simple concentric bands only ; no spines observed.

The two shell fragments have an ornament of double rows of concentric spine-bearing lamellae which merge together laterally. The alternating spines have a density of about 7 per millimetre along the lamellae, and attain a length of 0·5 mm.

Discussion. The genus *Multispinula* was erected by Rowell (1962 : 147) to include forms previously referred to *Schizambon*, but which possess a pseudointerarea

and a regular spinose ornament anteriorly. The fragments under discussion are all regarded as belonging to one species, the lack of spines in the umbonal region and their presence anteriorly being typical of many species (e.g. *M. cuneatum* (Willard)). The double row of lamellae on the spinose fragments is seen to merge into a single row laterally ; accordingly the presence of only a single row in the young umbonal stages may be expected, and thus does not conflict with the belief that all fragments belong to the same species. An accurate specific determination from this material is not possible.

Multispinula sp. 2

(Pl. 4, fig. 7)

One fragment of this genus (BB. 29899) is separated from the above species, being characterised by a distinctly punctate surface, well seen on the posterior side where the spines are not developed ; by finer, more slender spines (9 per mm.) arranged in single rows ; and by the absence of concentric lamellae, the spines arising in concentric rows directly from the shell surface.

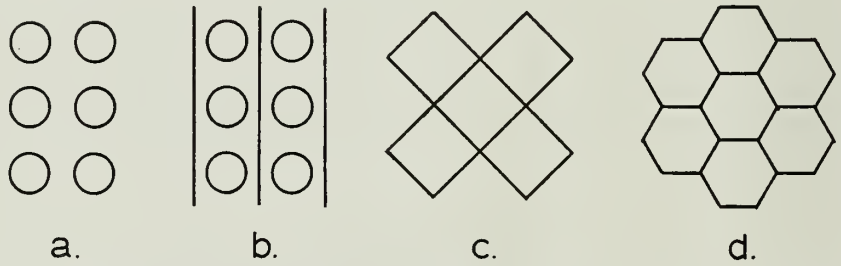

Fig. 5. Diagrammatic representations of the different styles of ornament in the genus *Trematis* : " a "—radial rows of pits ; " b "—radial rows of pits separated by radial ribs ; " c "—pits arranged in quincunx ; " d "—pits arranged hexagonally.

Superfamily **DISCINACEA** Gray

Family **TREMATIDAE** Schuchert

Genus ***TREMATIS*** Sharpe, 1848

The most distinctive features of this genus are the large pedicle notch of the ventral valve and the unusual ornament. The latter is commonly described as consisting of " small pittings . . . arranged either in quincunx or in radiating rows " (Hall & Clarke, 1892 : 139) ; further distinctions are made on the shape of the pits, and in the second case, on the presence or absence of radial ribs between the rows.

A review of the species ascribed to the genus leads the present writer to the conclusion that there are four basic types of ornament within the genus as understood at present. These are shown diagrammatically in Text-fig. 5. In style " a " the pits are arranged radially but are not separated by ribs as in " b ". Style " c " shows a

true quincuncial arrangement, and " d " the commoner hexagonal or honeycomb pattern.

These four basic types do show a certain amount of variation and intergradation. In the Portrane specimens, which are dominantly quincuncial, the pits on part of the shell show a honeycomb pattern. Irregularities of pattern have also been recorded by Wilson (1946 : 23) for the quincuncial *T. terminalis*. Accordingly, it seems doubtful that the quincuncial arrangement seen in *T. parva* will indicate a new genus as suggested by Cooper (1956 : 274), and further, although the majority of species of the genus do not have this pattern, it is developed in the type species (Sharpe, 1848 : 68, Text-figs. 1–3). In Emmons' original figures of *Orbicula terminalis* (1842 : 395, Text-fig. 4) the pits are not shown, only radial ornament being shown on the ventral and only concentric on dorsal valves.

Using the pit arrangements of Text-fig. 5 as a basis, most of the species may be placed in four corresponding morphological groups ; for example, style " a " is typical of *T. umbonata* Ulrich, *T. oblata* Ulrich, *T. punctostriata* Hall, *T. corona* Salter ; style " b " of *T. siluriana* Davidson, *T. cancellata* (G. B. Sowerby), *T. ottawaensis* Billings, *T. crassipuncta* Ulrich, *T. huronensis* Billings, *T. minneapolis* (Sardeson), *T. foerstei* Cooper ; style " c " of *T. parva* Cooper, *T. melliflua* Reed, *T. terminalis* (Emmons), *T. quincuncialis* Miller & Dyer ; style " d " of *T. punctata* (J. de C. Sowerby), *T. millepunctata* Hall, *T. craigensis* Reed.

Two of Cooper's species cannot be satisfactorily placed in this grouping. *Trematis? spinosa* is described simply as having " densely crowded pits ", which are too fine for the style to be ascertained from the accompanying figures. The species is however quite distinctive in possessing spines. The large, elliptical shaped pits of *T. elliptopora* are irregular and " crudely quincuncial " (Cooper, 1956 : 271) as are the Portrane shells, and so may be classed rather dubiously with style " c ".

T. fragilis also appears to belong to group " c ", for although Ulrich's figured specimen (1889 : 378, fig. 6) is by no means well preserved, it does show a quincuncial arrangement on a posterior fragment of the shell. *T. montrealensis* shows only concentric ornament on the single valve described by Billings (1862 : 52, fig. 57) and accordingly the position of this species is unknown.

Trematis sp.

(Pl. 4, figs. 3, 4, 8)

Description. Minute, subcircular, gently and evenly convex dorsal valves (BB. 29884–85), lacking fold or sulcus. Well developed crudely quincuncial ornament, and occasional well-marked growth stages. In the better of the two specimens, pits are not developed until after the first half millimetre. Anteriorly the ornament shows some variation, a hexagonal pattern replacing the typical quincunx in places. The quincunx may also be lost laterally, where the pits are larger.

Dorsal interior with a thickened posterior margin, divided by a broad median groove. Length of one incomplete dorsal valve (BB. 29884), 1·4 mm.

Ventral valve unknown.

Discussion. In the rather crude quincuncial pit arrangement, especially with the larger, more rounded pits situated laterally, the Portrane shell shows a strong resemblance to *T. elliptopora* Cooper, from the Pratt Ferry formation. The distinctive feature of the latter is that the pits are normally longitudinally elliptical. Those of the Portrane shells are of rather variable outline, but where the pits are elliptical, they differ from those of *T. elliptopora* in being transversely elliptical.

Amongst the British species, *T. corona* Salter occurs in the Cross Fell Corona Beds, and forms close to this have been found in the overlying Dufton Shales as high as the Actonian Stage (Dean, 1959 : 207). In the corresponding stage in Shropshire the genus is represented by *T. punctata* (J. de C. Sowerby) (Dean, 1958 : 223). Neither these, nor *T. craigensis* and *T. siluriana* from the Girvan Ordovician (Reed, 1917 : 818, 819) are close to the Portrane form, as all lack the typical quincuncial arrangement of the pits. Only *T. melliflua* Reed from the Balclatchie mudstones possesses this type of ornament.

Twenty-four pits per millimetre were counted along a line oblique to shell growth on Reed's figure of this species (1917, pl. 4, fig. 10*a*). For a Portrane valve a count of twenty pits per millimetre was observed, but this attribute certainly varies over the shell surface. Thus as far as can be ascertained the two forms are comparable in density of ornament, but the quincuncial arrangement is far less variable in *T. melliflua*.

The Portrane shell differs further in lacking the pronounced dorsal sulcus and transverse outline of the Balclatchie shell. From the figures of both Reed and of Williams (1962, pl. 7, fig. 22) it may be seen that the sulcus is quite clear at the 1 mm. growth stage, so that the lack of sulcus in the Portrane shells is not a reflection of their much smaller size.

The nature of the Portrane shells shows that they are quite distinct from the other quincuncial species of the genus, but until more complete material is obtained it is considered better to regard these shells as *Trematis* sp.

Family **DISCINIIDAE** Gray

Subfamily **ORBICULOIDEINAE** Schuchert & Le Vene

Genus ***ORBICULOIDEA*** D'Orbigny, 1847

Orbiculoidea shallochensis Reed

(Pl. 3, figs. 3, 7, 11, 16, 17, 24, 25)

1861. *Discina* (*Orbicula*), small sp., Baily, p. 11.
1880. *Discina* ; species undetermined, Baily, p. 82.
1895. *Discina* sp., Sollas, p. 102.
1917. *Orbiculoidea shallochensis* Reed, p. 820, pl. 4, figs. 18–20.

Description. Subcircular, biconical valves. Ornament of fine, even concentric ridges except at the umbones, which are smooth. For the best preserved shell,

counts of these ridges taken over the 1–2 mm. and the 2·5–3·5 mm. positions anterior to the beak, were 16 and 15 per millimetre respectively, showing little increase in thickness of the ridges with shell growth.

Ventral valve with subcentral apex; lateral profile of posterior surface gently convex, and anterior surface gently concave; evenly conical in anterior profile. Pedicle groove broadly lanceolate, extending a quarter of the distance from the apex to the posterior margin, with the small foramen restricted to the posterior extremity.

Dorsal valve initially conical, flattening somewhat later, with the apex one fifth of the length of the valve from the posterior margin. Lateral profile with a flat or slightly concave, relatively steep posterior slope, and a flat, gentler anterior slope; anterior profile a low even cone, flattening laterally.

Ventral interiors of fragments ascribed to this species show the pedicle tube clearly; little is seen in the dorsal interiors except for two faint, slightly divergent raised lines arising at the apex of the valve and continuing anteriorly for a short distance (*c.* 0·5 mm.).

Dimensions. Dorsal valve (BB. 29887): length 4·4 mm., width 4·6 mm.

Discussion. The Portrane shells agree with Reed's specimens from the Whitehouse Group, Girvan, in all features described by Reed and those evident from his figures (1917, pl. 4, figs. 18–20). The ornament is identical in style and in density (a count anterior to the 1 mm. distance from the apex on Reed's figure 19 gives 15 ridges per millimetre compared with 16 for the Portrane shell; the valve outline and profile are also similar. The dorsal apex is further forward in the figured Whitehouse valve (distance from the posterior margin is 24% of the valve length as opposed to 20% for the Portrane valve) and the pedicle groove is slightly longer in Reed's figure. These differences, however, appear to be well within the limits of normal variation and certainly do not merit separating the two forms, especially on the small quantity of material available for study.

Orbiculoidea sp.

(Pl. 4, figs. 1, 2, 6)

One discinid dorsal valve (BB. 29889) is quite distinct from *O. shallochensis*, differing in the unusual transversely suboval outline. The valve is somewhat broken anteriorly, but measurement on a growth line shows the length to be 65% of the width. The valve (width 4·2 mm.) is quite deep (0·9 mm.), the maximum thickness being just anterior to the apex. The beak itself is directed posteriorly, projecting slightly over the steep, flat, posterior slope. Anterior slope convex; anterior profile evenly convex.

The ornament is even, as in *O. shallochensis*, but slightly coarser (13 ridges per millimetre anterior to the 1 mm. distance from the apex). Interior with a light forked ridge traversing the posterior half from just anterior of the apex to the middle of the posterior margin.

Genus *SCHIZOTRETA* Kutorga, 1848

Schizotreta concava sp. nov.

(Pl. 4, figs. 5, 9, 10, 12–14)

Diagnosis. *Schizotreta* of sub-circular outline ; ventral valve conical with convex posterior slope ; dorsal valve concave, after short initial convex stage. Dorsal apex close to posterior margin ; ornament of rather coarse, concentric growth ridges which coalesce in posterior part of valve.

Holotype. Dorsal valve (BB. 29890) 4·6 mm. long.

Paratypes. Dorsal valve (BB. 29891) : length 1·4 mm., width 1·4 mm. Dorsal valve (BB. 29892) : width 6·1 mm. Other ventral fragments (BB. 29893–95).

Description. Outline subcircular to slightly elongate, young valves circular (3 small valves each have a length : width ratio of 100%). Fragments indicate a highly conical ventral valve with a convex posterior slope ; pedicle groove short, elliptical, listrium grooved medianly. Dorsal valve evenly convex for the first millimetre or so, afterwards flattening and becoming concave. Apex close to the posterior margin, the distance being 15% of the valve length for each of two adult valves, but much less for young valves (e.g. 4, 6, 7%). Apex smooth, an ornament of concentric ridges developing and becoming progressively coarser with increased growth ; between 1 and 2 mm. anterior to the apex, 12, 13, and 14 ridges were counted on three valves ; two valves gave counts of 5, 6 ridges between 3 and 4 mm. in front of the apex. The numerous ridges of the anterior of the shell tend to fuse together in the posterolateral regions to give the relatively small number of thickened ridges between the apex and the posterior margin.

Only the ridge forming the inner side of the pedicle tube is seen in the interiors of the ventral fragments. The tube terminates well inside an unthickened posterior margin.

Dorsal interior with a short lenticular groove situated medianly just inside the posterior margin, slightly anterior to which is a narrow arcuate band, apparently for muscular attachment. This band is about half the valve width, and possesses a pair of deeply inserted muscle pits medianly. In mid-valve, two adductor scars unite antero-medianly to produce a V-shaped scar, posterior to which is a faint ridge. This ridge also appears on the anterior side where it is bounded by the slightly divergent grooves of the *vascula media*. The punctae of the shell substance are clearly seen in the areas away from the muscle scars.

Discussion. The shells of this species are much thickened, and the internal structures obliterated except in one exquisitely preserved young dorsal valve. It is on this valve that the description of the interior is based.

Several of the features of *S. concava* are to be found in other species, but their combination in this species is quite distinctive. *S. conica* Dwight from the Trenton of New York shows similarities in valve profile and in the dorsal interior. It differs in having the dorsal beak much farther forward, which means that there is also no crushing up of the concentric ridges at the posterior border as in *S. concava* Dwight's comment on the variability, particularly of the ventral profile, in *S. conica* (1880 : 452) also seems pertinent to *S. concava*.

The convex posterior slope seen in the ventral valve of *S. posteroconvexa* Cooper (1956), also characterises the Portrane shell. The features of the dorsal valve of Cooper's species are not known as it based only on two ventral valves, but the ornament is finer and more evenly spaced than in *S. concava*. The Portrane shell is comparable with *S. shuleri* (Willard) in dorsal outline, position of apex, and in a count of 5 ridges per millimetre at 3 mm. from the apex (taken from Cooper, 1956, pl. 21, D, fig. 22) ; Willard's species does not show the concavity typical of the Portrane shell, nor has the ventral valve a convex posterior slope.

S. willardi Cooper from the Pratt Ferry formation is undoubtedly the closest known species to the Portrane shell, but not close enough for the possibility of the two being conspecific. Although only fragments of the Portrane ventral valve have been recovered, it would appear to be much more convex than the Pratt Ferry form ; more definite differences are to be seen in the concentric ridges of the dorsal valve, although in outline, profile, and the position of the apex it might be taken for *S. concava*. Whilst the ornament too is of the same general pattern, it is very much finer, 11 ridges being counted over the 3–4 mm. position in one of Cooper's figured dorsal valves, and 10 on another broken valve in about the same position. The concentric ridges also arise much later, the valves being smooth for about 2 mm. distance from the umbo compared with under 1 mm. for the Portrane valves (eight Portrane dorsal valves gave a mean of 0·79 mm. (var. 0·027) for this measurement).

S. concava may be differentiated from associated species of *Orbiculoidea* by the coarser ridges, valve profiles, and in the case of *Orbiculoidea* sp., valve outline.

Schizotreta sp.

(Pl. 3, figs. 18–21)

One ventral valve (BB. 29896) is separated from *S. concava* on account of its unusual ornament. There is reason to believe, however, that this is a pathological specimen, and it may possibly belong to *S. concava*.

The shell is broken marginally but is of subcircular outline, with a straighter posterior margin and apex slightly posterior to mid-valve. In profile the posterior slope is convex, and the anterior slope concave as in *S. concava*. The anterior profile is asymmetrically conical (approximate measurements ; length 5, width 3·5 and thickness 3 mm.). The pedicle groove is lanceolate, 1·2 mm. long, and representing about a third of the distance from the umbo to the posterior margin.

The ornament consists of strong, narrow, raised ridges separated by wide flat interspaces so that there are only 3 ridges per millimetre anterior to the 1 mm. distance from the umbo. The interspaces themselves are ornamented by extremely fine ridges or growth lines (5 being counted between two of the larger ridges). Some of these thicken up as they are traced to the anterior, where seven of the stronger ridges were counted per millimetre in the 1–2 mm. position. Converse to normal development, the stronger ridges become closer together towards the margin. A deep cleft on one side of the valve suggests that this is a pathological or, at least, an injured specimen.

Internally, the pedicle tube is clearly seen, and on either side of its continuation into the apex is a pair of deeply impressed almond-shaped adductor scars, aligned between the apex and the posterolateral angles. Two faint, narrowly divergent ridges are directed anteriorly from the apex, lateral to which is another pair of less well defined muscle scars.

Superfamily **CRANIACEA** Forbes

Family **CRANIIDAE** Forbes

Genus ***EOCONULUS*** Cooper, 1956

Eoconulus transversus sp. nov.

(Pl. 3, figs. 4, 8, 12, 13)

Diagnosis. Small, misshapen, cone-shaped chitinous valves, umbones slightly posterior to mid-valve. Outline transverse, length about two-thirds of width. Posterior margin straight, slightly wider than anterior margin, anterolateral and posterolateral extremities rounded. Posterior slope steeper than anterior slope in 5 out of 8 valves ; shallow sulcus in anterior slope. Ornament of concentric growth lines, occasionally thrown into strong undulating wrinkles.

Interior with two large sub-reniform adductor scars situated posterolaterally, and extending for half valve length. Short, thickened, tripartite ridge, aligned subparallel to margin sometimes seen posteromedianly.

Ventral valve not known.

	Length	Width
Holotype. BB. 29900	1.3 mm.	1.75 mm.
Paratypes. BB. 29901	1.3 mm.	2·2 mm.
BB. 29902	1.55 mm.	2.3 mm.
BB. 29903	—	1.55 mm.

Discussion. This interesting genus is known only from the dorsal valve ; the ventral valve, which was evidently attached, has not been recovered by either Cooper or the present writer. Cooper (1956 : 283) obtained specimens from two horizons both older than the Portrane Limestone ; from the Botetourt Formation in Virginia and from the Pratt Ferry Limestone of Alabama. The specimens from the former locality are the larger and " differently shaped ", but are not good enough for description. The second locality yields the one described species, the type species *E. rectangulatus* Cooper. The size of the Portrane shells is similar to that of the type species, but the differences between the two forms necessitate the erection of a new species for the Portrane shells.

The following statistical data give a comparison of shell shape for the Portrane and Pratt Ferry shells, the dimensions for the latter being taken from Cooper's data.

(a) *Ratio length : width of dorsal valves.*

E. transversus sp. n. :—59, 60, 63, 67, 69, 74, 77% ; mean = 67% (var. 47·0).
E. rectangulatus Cooper :—66·7, 70, 75, 79, 86% ; mean = 75·4% (var. 56·3).

A Rank Sum Test gives p = 0·053, indicating that although the Portrane shell is more transverse than the Pratt Ferry shell, the difference is not significant, p being just over the 5% level.

(b) *Ratio height : width of valves.*

E. transversus :—29, 33, 34, 37, 37, 40, 43, 53% ; mean = 38·25% (var. 53·9).
E. rectangulatus :—36, 38, 56, 57, 60 ; mean = 49·4% (var. 55·8).

A Rank Sum Test indicates p = 0·047, thus the relatively low valves of *E. transversus* in transverse profile are significantly different from those of the type species.

(c) *Ratio height : length of valves.*

E. transversus :—38, 54, 54, 55, 56, 58, 64% ; mean = 54·1% (var. 62·8).
E. rectangulatus :—45, 57, 67, 75, 86% ; mean = 66% (var. 251·0).

On testing, these figures show no significant difference in the longitudinal profile of the two species.

E. transversus differs from *E. rectangulatus* in its lower conical transverse profile, and in the presence of a median sulcus on the anterior slope of the shell. Six of the complete valves show an ornament of simple concentric growth lines, but one specimen also has strong undulating wave-like wrinkles. This ornamentation is rather similar to that of *Undiferina* Cooper (1956). However, there is little doubt as to the affinities of this Portrane valve, as another valve shows an intermediate stage between it and the more usual type, showing a few wrinkles developed on part of the shell only. This irregular surface with variable wrinkles is of course typical of many craniaceids.

Genus *ACANTHOCRANIA* Williams, 1943

Acanthocrania was erected as a subgenus of *Crania* to include " Cranias with dorsal valves ornamented by fine papillae or fine spines " (J. S. Williams, 1943 : 71). The type species, *C. spiculata*, is a Carboniferous form, but Cooper (1956 : 283) records the genus as being widely distributed and fairly abundant in the Ordovician of North America. Gorjansky (1960 : 177) does not record the genus from the U.S.S.R., but there is no doubt that three Estonian forms [von Huene, 1899, *Philhedra pustulosa* (p. 298), *P. hemipustulosa* (p. 304) and *Craniella papillifera* (p. 317)] may be referred to this genus as at present defined.

Neither the genus nor any craniaceid referable to it, have been previously described from the British Isles. Although the genus is not common at Portrane, there appear to be two distinct forms represented.

Type species. *Crania spiculata* Rowley (1908).

Acanthocrania cracentis sp. nov.

(Pl. 4, figs. 22, 25, 26)

Diagnosis. Dorsal valve deep, transversely subcircular with straight posterior margin. Anterior profile asymmetrically convex; lateral profile evenly convex anterior to beak, steep and gently concave posterior to beak. Maximum valve thickness at mid-valve; beak situated posteriorly, curved over towards posterior margin and below greatest height of valve. Ornament of well marked growth lines giving somewhat lamellose appearance, and fine spines (those preserved being up to 0·3 mm. long), exact relation of spines to growth lines being obscured by silicification.

Interior with pair of large rounded anterior adductor scars (length $\frac{1}{4}$ of the valve length) situated slightly posteriorly to centre of valve and separated by groove along which is a low ridge, extending anteriorly. Posterior adductor scars transversely oval, about half the length of anterior pair, situated in front of posterior submarginal groove, where they are separated by raised median area.

Ventral valve not known.

Holotype. BB. 29904; length 4·4 mm., width 5·0 mm., thickness 2·1 mm.

Discussion. The distinctive lateral profile, with the umbo situated below the maximum height and the posterior position of the umbo, serve to differentiate the new species from all others except *A. spinosa* Cooper. The Portrane form differs from this species in its much neater form, regular outline, finer spinose ornament and clearer concentric ornament.

Acanthocrania sp.

(Pl. 4, figs. 11, 15, 16, 19)

Description. Three incomplete irregular dorsal valves (BB. 29905–07) of sub-rounded outline, gently to strongly convex profile. Apex posterior of mid-valve; posterior slope flat to concave, anterior slope convex. Irregular concentric ornament covered by coarse stout spines 0·5 mm. or more in length. Interior with a pair of large muscle scars situated posteriorly to the centre of the valve, and separated by a smooth groove which develops anteriorly into a ridge. Here it is bounded by two impressed areas which bear vascular markings in the form of radiating ridges. Width of one incomplete dorsal valve (BB. 29905), 8·8 mm.

Discussion. Whilst the incomplete nature of these shells (especially posteriorly) prevents their specific determination, sufficient features are preserved to distinguish them from the associated *A. cracentis*.

The shells differ from *A. cracentis* in possessing a much coarser spinose ornament, a very variable and irregular profile, and a beak which is relatively farther from the posterior margin and which does not overhang the posterior slope. (It should be mentioned that the position of the beak was not established for one valve because of its very coarse silicification).

Internally the groove separating the anterior adductor scars lacks the median ridge of *A. cracentis*, but this does not seem to be a specific character, the variable nature of its occurrence being recorded for *A. pustulosa* by von Huene (1899 : 298).

Genus *PHILHEDRELLA* Kozlowski, 1929

This genus was erected as a subgenus of *Philhedra* Koken (1889) by Kozlowski (1929 : 40) for those forms closely resembling *Philhedra* but which possess a smooth or concentrically ornamented surface, lacking the radial ornament of *Philhedra s.s.*

Philhedra was originally placed in the Gastropoda by Koken (1889 : 465) although he later (1897 : 112) placed it close to the craniaceid brachiopod *Pseudocrania*. This was accepted by von Huene (1899 : 297), who, although he subdivided the species into two groups based on this differing ornamentation, did not rate this character as constituting a basis for further generic distinction. Von Huene considered the large size of the anterior adductor scars relative to that of the posterior adductor scars to be a more important character, this feature differentiating *Philhedra* from *Petrocrania* Raymond 1911 (*syn. Craniella* Oehlert *non* Schlotheim, 1820).

Kozlowski (1929) sub-divided Koken's genus on the ornamentation, since when the name *Philhedra* has been generally restricted to those shells possessing radial ornament (Maillieux, 1936 : 46 ; Cooper, 1944 : 291 ; Gorjansky, 1960 : 176).

Unfortunately the type species of *Philhedrella, P. mimetica*, is very inadequately known, no information being available on either the ventral valve (which is generally thought to be extremely thin or non-existent in the genus (Kozlowski, 1929 : 41 ; Cooper, 1956 : 284)) or the all important dorsal interior. Thus the type species is just as likely, on present evidence, to belong to *Petrocrania* as to the smooth *Philhedra, Philhedrella*. Re-investigation of the type species may lead to the suppression of *Philhedrella*, in which case a new name will have to be erected for the forms with a *Philhedra*-like interior but a smooth or concentrically ornamented exterior.

One of the Portrane craniaceid species possesses these characters and is here included in the genus *Philhedrella*, at least until such time as the type species is re-investigated.

Type species. *Philhedrella mimetica* Kozlowski (1929 : 40).

Philhedrella celtica sp. nov.

(Pl. 4, figs. 17, 18, 20, 21, 23, 24)

Diagnosis. Dorsal valve large, sub-conical with long, almost straight posterior margin, whose width approaches maximum valve width. Apex unobtrusive, situated posterior to mid-valve. Interior with large adductor scars, anterior pair larger than posterior pair, which abut upon posterior margin.

Holotype. BB. 29908. Length about 22 mm.

Paratype. BB. 29909. Width about 22 mm.

Description. Large subconical dorsal valve, apex situated posterior to mid-valve. Anterior profile a low cone ; lateral profile with a gently convex anterior slope and flat or gently concave posterior slope, the latter forming a triangular area bounded by the straight, but somewhat irregular, posterior margin. Postero-lateral angles sharply obtuse, lateral margins gently convex, the curvature increasing at the antero-lateral angles to form a straight anterior edge medianly. Valve

surface rather uneven, ornamented by fine growth lines and developing irregular concentric wrinkles on large shells.

Dorsal interior with large anterior and smaller posterior pairs of adductor scars, the posterior edge of the latter lying on the valve margin. The former are sub-oval (width about $\frac{3}{4}$ of the length), swollen and extending almost a third of the valve length in the holotype. They are situated anterolaterally to the valve apex and are well separated by a groove (more than half the width of an individual scar), along which is a low ridge. This broadens anteriorly forming a thickened margin to the scutellum, from which a median ridge (rostrum) and two less well marked antero-lateral ridges project. Posterior adductor scars of subtriangular outline, with the apex directed anterolaterally. Width similar to anterior scars, but only half the length. Smaller muscle scars situated lateral to these, in the posterolateral corners of the shell. The depressed areas on either side of the rostrum show a series of parallel pallial ridges, roughly perpendicular to the margin, which may be traced towards the posterolateral angle.

Ventral valve unknown.

Discussion. The material consists of three sub-conical dorsal valves, together with two other fragmentary specimens. The latter show the same pair of very large swollen anterior adductor scars, one being a very low cone with poor concentric ornament, the other flatly convex. The broken nature of these shells, which are believed to be flattened areas of larger conical valves, prevents their being used in the systematic description of the species.

The Portrane shells are quite distinct from the other Ordovician craniaceids which may belong to this genus. One of these is *Crania trentonensis* Hall, for which figures of the diagnostic dorsal interior are unknown to the writer, but which has been placed in the genus *Petrocrania* by Cooper (1956 : 290). Whether this generic assignment is correct or not, the valve outline alone is sufficient to distinguish the species from the Irish form, as it lacks the straight posterior margin of the latter, and also has its greatest width towards the anterior margin (see Hall & Clarke, 1892, pl. 4, H, fig. 21).

Of the Estonian forms which have the features of *Philhedrella*, *P. acra* (von Huene, 1900 : 179) resembles the Portrane shell in its development of a steep, triangular posterior surface, but differs in its smaller size, the narrow posterior margin relative to valve width and the clearly defined button-like apex. *P. glabra* has a similar profile, but the outline lacks the long posterior margin of *P. celtica* whilst the interior has small, oval posterior muscle scars, situated well inside the valve margin. The sole specimen of *P. mitrata* again lacks the distinctive outline of the Portrane shell ; von Huene's figure is not very clear (1899, pl. 5, fig. 6). *P. bucculenta* differs in its sub-central button-like apex and round outline, whilst *P. despectata* also lacks the straight posterior margin and triangular surface posteriorly.

P. kokeni, which ranges up into the Rakvere stage, resembles *P. celtica* in size and general appearance of the exterior, although of a somewhat more subquadrate outline. Internally the differences are very marked, the Estonian form having oval posterior adductor scars situated well away from the margin, and anterior ones which are " bean-shaped " and which converge anteriorly.

No craniaceid species comparable with *P. celtica* are recorded from the British Isles.

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PLATE 1

Lingulella sp. 1 . . . . . p. 230

FIGS. 1, 2. Interior and exterior of dorsal valve. BB. 28219. ×12.

FIGS. 3, 4. Interior and exterior of dorsal valve, broken anteriorly. BB. 28220. ×12.

Lingulella sp. 2 . . . . . p. 230

FIGS. 5, 6. Interior and exterior of dorsal valve. BB. 28221. ×12·3 and 13·2 respectively.

Lingulella sp. 3 . . . . . p. 231

FIGS. 7, 13. Interior and exterior of a broken ventral valve, the latter showing fine growth lines with a stronger concentric line at regular intervals on one side of the shell. BB. 28222. ×8·5.

Rowellella minuta gen. et sp. nov. . . . . p. 233

FIGS. 8, 14, 15. Anterior, internal and lateral views of incomplete dorsal valve. Paratype, BB. 28226. ×26.

FIGS. 9–11, 16. Ventral, dorsal, lateral and posterior views of the holotype, BB. 28223. ×27.

FIGS. 12, 17–19. Ventral, posterior, lateral and dorsal views of paratype, BB. 28224. ×27.

FIGS. 20, 21, 27, 28. Posterior, anterior, internal and external views of incomplete dorsal valve. Paratype, BB. 28228. ×12.

FIGS. 22–24. Lateral, external and internal views of incomplete dorsal valve. Paratype, BB. 28225. ×26.

FIGS. 25, 26. External and internal views of incomplete dorsal valve. Paratype, BB. 28227. ×14.

Acanthambonia portranensis sp. nov. . . . . p. 231

FIG. 29. Interior of dorsal fragment. Paratype, BB. 29863. ×12·5.

FIGS. 30, 31. Exterior and interior of ventral valve. Holotype, BB. 29860. ×9·7.


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PLATE 2

Leptobolus rarus sp. nov. . . . . p. 232

FIGS. 1, 2. Interior and exterior of incomplete ventral valve. Holotype, BB. 28229. ×16·5.

Paterula cf. *perfecta* Cooper . . . . . p. 235

FIGS. 3, 4, 9, 16. Four fragmentary ventral valves showing the muscle and pallial markings of the valve interior. BB. 29864–67. Figs. 3, 4×15; Figs. 9, 16×20.

FIG. 5. Interior of a dorsal valve, muscle scars not prominent. BB. 29868. ×11·5.

FIG. 8. Interior of an older dorsal valve, muscle field well developed. BB. 29869. ×10·5.

FIGS. 10, 13. Internal and external views of an almost complete ventral valve. BB. 29870. ×12.

Scaphelasma? sp. . . . . p. 240

FIGS. 6, 7. Exterior and interior of dorsal valve. BB. 29883. ×19.

Spondylotreta cf. *parva* . . . . . p. 239

FIGS. 11, 15. Dorsal fragments showing the features of the interior. BB. 29879, BB. 29880. ×6, ×6·5 respectively.

FIGS. 12, 14. Ventral umbonal fragments, the former showing pronounced pallial markings. BB. 29877, BB. 29878. ×6, ×11·4 respectively.

FIGS. 18, 19. Interior and exterior of a damaged dorsal valve. BB. 29881. ×6·3.

Spondylotreta parva sp. nov. . . . . p. 238

FIGS. 17, 20. Exterior and interior of a dorsal valve. Paratype, BB. 29873. ×15·6.

FIGS. 21, 25. Lateral and posterior views of a ventral valve, damaged marginally. Paratype, BB. 29874. ×14·6.

FIGS. 22–24. Ventral, oblique and lateral views of a damaged dorsal interior to show the muscle scars and strong median septum, this being slightly broken anterior to its apex. Paratype, BB. 29872. ×15·4.

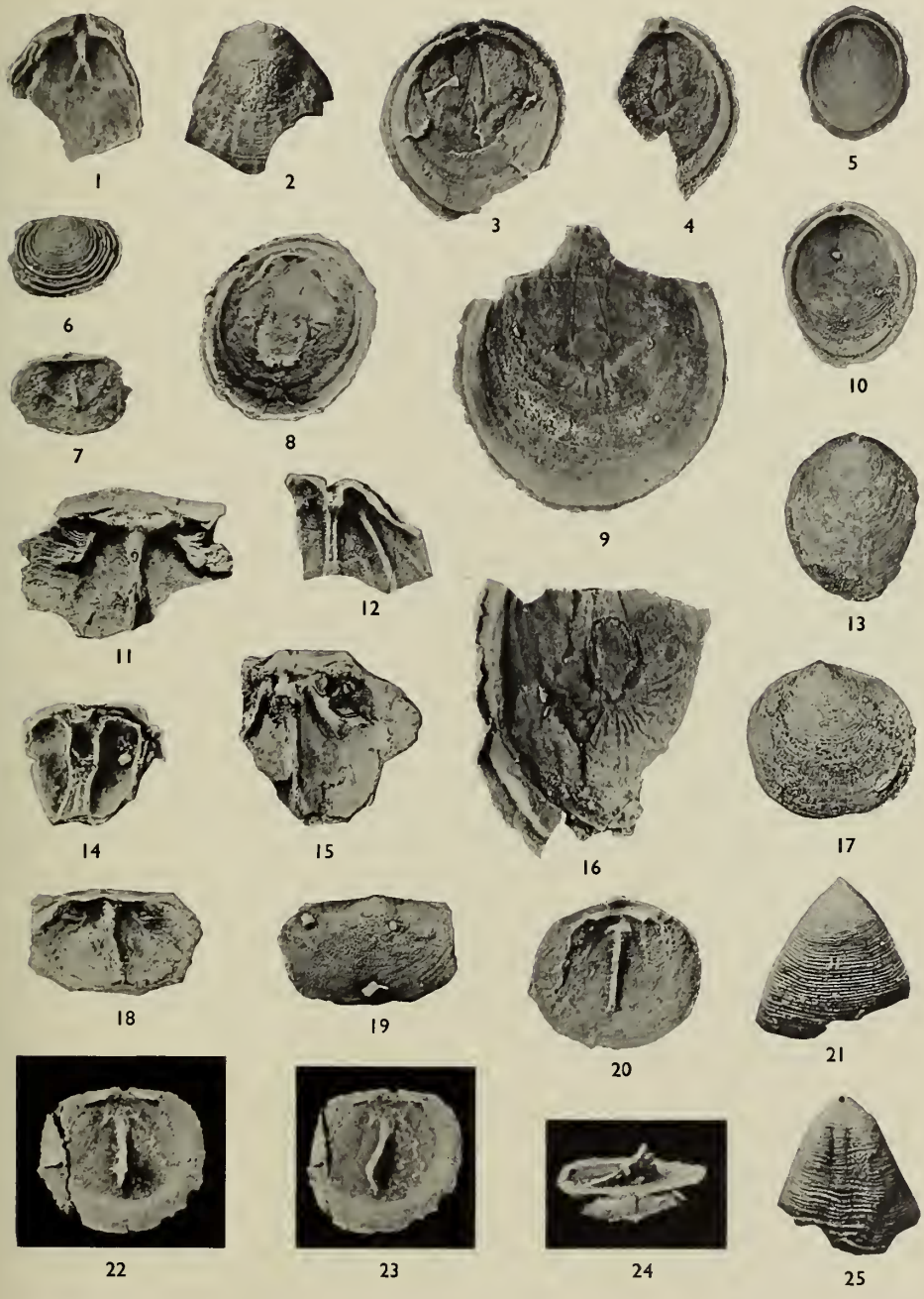
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PLATE 3

Spondylotreta parva sp. nov. . . . . p. 238

FIGS. 1, 5, 9, 15. Four views of the interior of the ventral valve to show the nature of the apical structures and pallial markings. Holotype, BB. 29871. ×24.

Ephippelasma? sp. . . . . p. 240

FIGS. 2, 6, 10, 14. Anterior, posterior, apical and lateral views of ventral valve. BB. 29882. ×22·5.

Orbiculoidea shallochensis Reed . . . . p. 244

FIGS. 3, 7, 11. Lateral, ventral and dorsal views of incomplete pair of valves. BB. 29886. ×6.

FIGS. 16, 17, 25. Interior and exterior of a dorsal valve. BB. 29887. ×3·5, and an enlargement of the interior, ×4·8.

FIG. 24. Interior of ventral fragment, showing pedicle tube. BB. 29888. ×6·2.

Eoconulus transversus sp. nov. . . . . p. 248

FIG. 4. Interior of dorsal valve. Holotype, BB. 29900. ×11.

FIGS. 8, 12, 13. Antero-dorsal, dorsal and posterior views of a dorsal valve. Paratype, BB. 29901. ×11·7.

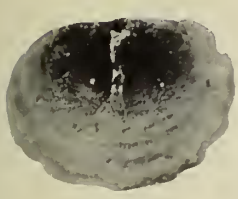
Schizotreta sp. . . . . p. 247

FIGS. 18–21. Lateral, oblique, ventral and internal views of a ventral valve. BB. 29896. ×3·3.

Multispinula sp. 1 . . . . . p. 241

FIG. 22. Incomplete ventral valve showing characteristic foramen. BB. 29897. ×21.

FIG. 23. Fragment of anterior part of a valve, showing ornamentation. BB. 29898. ×6·6.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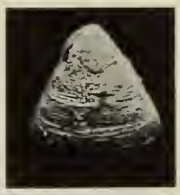
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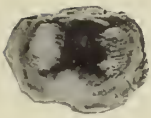
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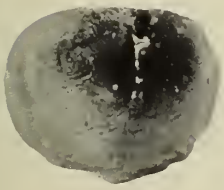
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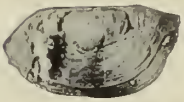
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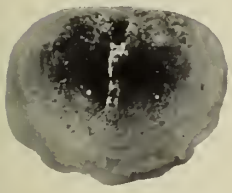
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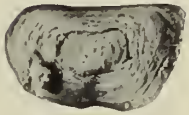
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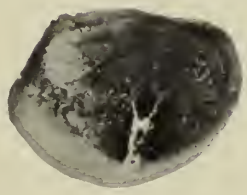
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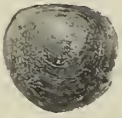
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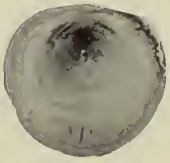
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PLATE 4

Orbiculoidea sp. . . . . p. 245

FIGS. 1, 2, 6. External, lateral and internal views of dorsal valve. BB. 29889. ×6.

Trematis sp. . . . . p. 243

FIGS. 3, 8. Exterior and interior of incomplete dorsal valve. BB. 29884. ×12·8.

FIG. 4. Exterior of a dorsal fragment. BB. 29885. ×13·2.

Schizotreta concava sp. nov. . . . . p. 246

FIGS. 5, 10, 14. Interior and exterior of a small dorsal valve, BB. 29891, ×10, and an enlargement of the interior, ×15. Paratype.

FIG. 9. Exterior of dorsal valve. Holotype, BB. 29890. ×3·7.

FIG. 12. Exterior of dorsal valve. Paratype, BB. 29892. ×2·7.

FIG. 13. Interior of ventral fragment showing pedicle tube. Paratype, BB. 29893. ×3·9.

Multispinula sp. 2 . . . . . p. 242

FIG. 7. Fragment of a valve showing ornamentation. BB. 29899. ×10·8.

Acanthocrania sp. . . . . p. 250

FIG. 11. Exterior of broken dorsal valve. BB. 29906. ×2·5.

FIGS. 15, 16. Anterior and dorsal views of incomplete dorsal valve. BB. 29905. ×2.

FIG. 19. Interior of incomplete dorsal valve. BB. 29907. ×1·9.

Acanthocrania cracentis sp. nov. . . . . p. 250

FIGS. 22, 25, 26. Internal, lateral and external views of dorsal valve. Holotype, BB. 29904. ×3·4.

Philhedrella celtica sp. nov. . . . . p. 251

FIGS. 17, 18, 21. Dorsal, lateral and internal views of dorsal valve. Holotype, BB. 29908. ×1·2.

FIGS. 20, 23, 24. Internal, lateral and dorsal views of a dorsal valve. Paratype, BB. 29909. ×1·4.


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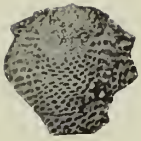
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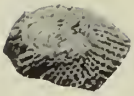
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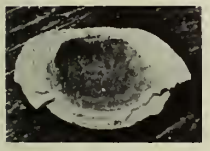
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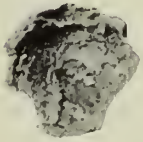
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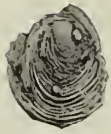
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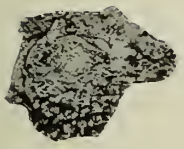
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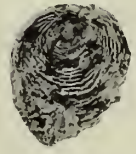
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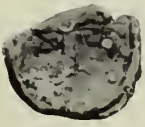
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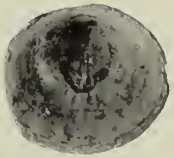
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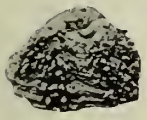
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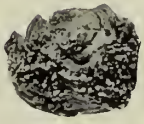
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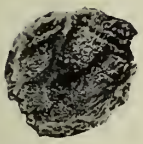
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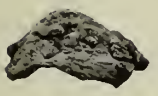
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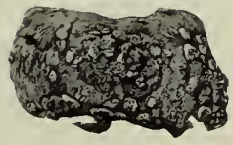
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